8.13 *Oil with an absolute viscosity of 0.16 N·s/m² and a density of 925 kg/m³ is flowing in a 200-mm-diameter pipe at 0.50 L/s. How much power is lost per meter of pipe length?*

SI

Eq. 4.7: $V = 4(0.000\,50)/(\pi 0.200^2) = 0.015\,92$ m/s

Eq. 8.1: $\mathbf{R} = [0.20(0.015\,92)925]/0.16 = 18.40$, flow is laminar. Eq. 8.29: $f = 64/18.40$

Eq. 8.14: $h_f/L = (64/18.40)(1/0.20)0.015\,92^2/[2(9.81)] = 0.000\,1796$ meter per meter

Eq. 5.41: Power loss $= (925 \times 9.81)(\pi 0.100^2)0.015\,92(0.000\,1796) = 0.000\,815$ watts per meter ◄

8.14 *Water at 50°F enters a pipe with a uniform velocity of $U = 14$ fps. (a) What is the distance at which the transition occurs from a laminar to a turbulent boundary layer? (b) If the thickness of this initial laminar boundary layer is given by $4.91\sqrt{\nu x/U}$ (from Eq. 9.10), what is its thickness at the point of transition?*

BG

Table A.1 for water at 50°F: $\nu = 1.410 \times 10^{-5}$ ft²/sec

(*a*) Sec. 8.10: At transition point (turbulent boundary layer begins): For $\mathbf{R}_x = 500{,}000 = Ux/\nu$

$x = 500{,}000\,\nu/U = 500{,}000(0.000\,0141)/14 = 0.504$ ft $= 6.04$ inches ◄

(*b*) Given: $\delta = 4.91\sqrt{\nu x/U} = 4.91\sqrt{0.000\,0141 \times 0.504/14} = 0.003\,50$ feet or 0.0420 inches ◄

16 *In a 36-in-diameter pipe velocities are measured as 18.5 fps at r = 0 and 18.0 fps at r = 4.0 in. Approximately what is the flow rate?*

BG

Eq. 8.40: $18.0 = 18.5 - 5.76u_* \log[18/(18-4.0)]$ from which $u_* = 0.795$ fps

Eq. 8.37: $0.795 = u_* = V\sqrt{f/8}$. Thus $f^{1/2} = 2.25/V$ (1)

Eq. 8.43: $V/18.5 = 1/(1 + 1.326f^{1/2})$ (2)

Eliminating f between (1) and (2): $\dfrac{18.5}{V} = 1 + 1.326\dfrac{2.25}{V}$, from which $V = 15.52$ fps (so $f = 0.0579$)

Eq. 4.7: $Q = AV = (\pi/4)(36/12)^2 15.52 = 109.7$ cfs ◀

8.18 *Water at 60°C flows in a 15-mm-diameter copper tube (e = 0.0015 mm) at 0.06 L/s. Find the head loss per 10 m, using Eq. (8.29) or (8.52) to find f. What is the centerline velocity, and what is the value of δ_v*

SI

Table A.1: At 60°C, $\nu = 0.474 \times 10^{-6}\ \text{m}^2/\text{s}$

Eq. 4.7: $V = Q/A = \dfrac{4Q}{\pi D^2} = \dfrac{4(0.06 \times 10^{-3})}{\pi(0.015)^2} = 0.340\ \text{m/s}$

Eq. 8.1: $\mathbf{R} = \dfrac{DV}{\nu} = \dfrac{0.015(0.340)}{0.474 \times 10^{-6}} = 10\,740$ (flow is turbulent) ; $\dfrac{e}{D} = \dfrac{0.0015}{15} = 0.000\,100$

Eq. 8.52: $f = 0.0304$; Eq. 8.13: $h_f = 0.031\dfrac{10}{(0.015)}\dfrac{0.340^2}{2(9.81)} = 0.1191\ \text{m}$ ◄

Eq. 8.43: $0.340/u_{max} = 1/[1 + 1.326(0.0304)^{1/2}]$; $u_{max} = 0.418\ \text{m/s}$ ◄

Eq. 8.38: $\delta_v = \dfrac{14.14(0.474 \times 10^{-6})}{0.340(0.0304)^{1/2}} = 0.000\,1132\ \text{m}$ ◄